Association of Educational Data Processing Symposium — Lecture

INTRODUCTION TO COMPUTER CONCEPTS

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I approach this task with some fear because I don't really know what you know about computers, or what you want to know about them. If someone feels that I have strayed off the track or am using words you don't know, or that I'm saying things of which you're painfully aware, I trust you'll interrupt me. Let me comment a bit on the history of computers to put it in reasonable perspective, and get our time scale straightened out.

Of course, there have been some computing aids for a long time, the abacus, and its ancestors, are at least a couple of thousand years old. However, the first more mechanized computing machine of which I know was built by Plain Pascal in the seventeenth centruy. It was an adding machine which he built for his father who was a customs man, and who thereby was able to work better. There was little further development until the last century during which several gentlemen had the vision of modern computers. Charles Babbage, who worked between about 1820 and his death in 1871 really understood what we now think of as a modern computer, but died quite frustrated because of the superhuman problems he encountered in implementation. As a matter of fact, those who reinvented computers in this century didn't know of his existence until after they had duplicated much of his conceptual work. Similarly, in the 1870's James Thompson, the brother of William Thompson, Lord Kelvin, developed some machines for solving differential equations. He too had difficulty with the implementation. Vanevar Bush about 1930 at MIT reinvented, with others, essentially the same machine that James Thompson had invented some fifty years earlier, at that time being unaware of what had been done. I find that the reports of both these early gentlemen are located in the

University of Utah library, and doubtless were located in the libraries of researchers who reinvented their machines. We didn't have the technology just a few years ago to support the computer art. As a matter of fact, it scarcely was available at the time of the first electronic computers just 20 years ago. Herman Hollerith, who was an employee of the Census Department prior to the 1890 Census became aware that it would not be possible to manually process the data for the 1890 Census, and set out to automate this task. He devised something similar to the modern punch card which was an adaption he made from the cards which were used to control the operation of the Jacquard Loom for weaving complex patterns. The important thing that he developed was the capability to represent information by holes punched into cards and to sort the cards based on the information. Computers have now gone a long way toward realizing one of the dreams of these pioneers. This particular dream is to free humans from large-scale, highly-repetitive clerical tasks. As a matter of fact, what's happened as a result of our having the punch card, and the capability to sort them plus more recent advances is that we have now built up such complex data processing requirements in our society, that we cannot operate society without the machines. The automatic telephone system is a set of computers. We now have such a large volume of telephone calls that it would take all of the women between the ages of 17 and 35 to operate the exchanges manually. We are already the slaves of these machines in that our society will not now operate without them. I agree with Dick Maxfield that we're certainly going to be more in the grasp of these things in the future. I don't view that as a tragedy, if we guide the development so as to save man. After I talk about the machines themselves a bit, I'll offer you my opinion about the relationship we should endeavor to establish between machines and humans.

There was another dream. I mentioned the dream of having machines which would free man from routine tasks. The other dream, characterized in the 1940 era by John Von Neumann, was that of extending human intelect, providing machines which could be used as aids to creative endeavor, to design, to teaching, to research in a variety of fields, not just in numerical processes but in research in many fields of application. We've been pretty successful in designing machines and systems which actually take over routine work. We've been much less successful in extending the human intellect by some working partnership between a machine and a man. I'd like to call this use of machine "computer-aided problem solving." Presently, people solve problems directly or people construct programs which are really recipes which direct computers in the process of performing computations. Such a program is in effect pushed through a slot in the door of the computer center; on the following day the results of the computation are returned to the user. The communication between the man and the computer is thus very limited. What we're beginning to see with new computing systems is greatly improved means of communication between men and machines. Certainly, computer-aided instruction is one of the areas in which we are sorely limited, not only by our understanding of the educational processes, but by our capability of building machines and systems which can communicate well with people. We're beginning to see some fruits of our experimental systems which we call interactive systems, with which people can communicate well. In some areas of research, particularly in computer-aided design the results are very satisfying.

Well, before proceeding further along this line, I'd like to talk about what is a computer. In the first place, let's think of a computer as being a programmable device, a device capable of following instructions. It can perform only simple arithmetical and logical operations. It can store intermediate results and choose one of two alternate instruction sequences depending on the result of previous computation. Instructing a computer is like instructing an unimaginative but faithful servant to solve a problem by use of an adding machine with the aid of a pencil and scratch paper for saving the results of computations for future use. We might instruct our servant by writing the instructions in English on a piece of paper, as a matter of fact, if I were preparing a set of instructions for a traditionally operated computer, I would also place the instructions for the computer on a piece of paper. Rather than writing these instructions in natural English, which is a very complex and somewhat ambiguous language, I write these instructions in some formally defined but highly restricted language. The language might be called FORTRAN, or it might be called COBOL. These are languages in which we completely understand the syntax, and have little doubt about semantics. Unfortunately the machine that we have isn't able to read the piece of paper on which the instructions are written. The information from the paper is therefore transcribed to punch cards where a pattern of holes in each column represents a symbol of my instructions. Now, the machine feels these holes or shines a light through these holes to discover what I've written and cause this information to be recorded in a set of electronic circuits, which we call the memory.

Information is arranged in this set of electronic circuits in a very orderly manner. We say that it is arranged by means of a structural coordinate, we give the number zero, say, to the first location at which a word may be recorded. We give the number one to the second location, the number two to the third location and so forth. It is in terms of these locations that the instructions to the machine are written. If certain information is required by the program, the program must specify the location by number.

If I were to look into the computer's memory, and just examine the content of locations in there, I would not be able to distinguish instructions from data, however, if I tried to execute data as instructions, I'd get some kind of nonsensical operation. The machine can treat the instructions as data and operate on them to modify the instructions which is one of the things that gives a modern machine greater capability than was available with some of the earlier types of machines. The capability of the machine to alter its course of computation and to modify its instructions as computation procedures is the thing that's really important in making these machines powerful.

Much effort is required to program a raw computing machine. However, many programs have been collected into libraries which perform many operations which are commonly required. Libraries of programs for computing mathematical functions, trigonometric functions, square roots and cube roots, and powers of numbers, and the functions of data processing, such as sorting, and many others are things that have been collected. Such a library is called a sub-routine library, having such a library, the task of constructing a program for doing a particular task is often made easy.

In addition to input, computation, and internal information storage elements a computer also has output elements. One output element is a machine that punches cards. The only reason to punch cards in a modern computing system is if the information is to be put back into the computer a later time. As a matter of fact, we don't punch many cards in our Computer Center now. We have other output devices. Printers, are able to print 600 to 1,000 lines per minute of 132 characters per line.

Magnetic tape systems are a common means of sorting information for later use by the computer. These systems are very similar to the home tape recorders, except that representations of numbers and letters are recorded. Information can be recorded much more rapidly and read more rapidly and stored in a much smaller space than the corresponding information punched in the punched card. Also we can't reorder a sort the elements of information on the magnetic tape without copying them to another tape.

All of these input and output operations are simply translations of the information representations. There are electrical representations, representations in terms of the state of magnetization of little magnetic cores in the computer or representations on the punch card in terms of the pattern of holes in the card. On this paper, information is represented in terms of the shape of the symbol written. Onpunched paper tape or cards we have patterns of holes.

Surely we're all steeped in new math, so we'll understand the binary representations which are ordinarily used inside computers. The internal representation need not be of concern to a user because the computers have sub-routines, prepared recipes, to convert internal representations to the familiar decimal numbers and alphabetic symbols. One should choose machines on other bases than the internal number representation.

A blackboard demonstration of programming was conducted. It was illustrated that in many tasks the same set of instructions are executed many times by a computer in solving a problem, thus making programming a reasonable task.

This is the end of the programming course, now I's like to talk to you a bit about the relationship between programmers, users, and computers. We're going outside the box again now, I just wanted to convince you that what is inside the box is interesting and not terribly frightening. I may not have succeeded in communicating with you but one thing you should know is that you can each understand a computer and each of you has the capability to write a computer program. I would say further that I believe firmly that the improvement in computer languages and the improvement in the means by which people and computers can communicate with each other is leading us in the direction in which it is getting progressively easier for the end user of the computer to do his own programming. I foresee the time when for most of our programming it will be easier for us to do it ourselves than to tell a professional programmer what we want done. I expect to see the ability to use computers become as common on ability as to use a typewriter.

The traditional mode of operating a computing system now is one in which the machinery resides in a place called the computer center. It is cared for and tended by a group of professionals, and these professionals do all the operation of the machine. That is called a closed shop. The programming may also be a closed shop or open shop, that is professional programmers writing all programs a free choice by the users. At the present time, one should have a professional programming staff and the freedom for users to write their own programs. People should be encouraged to learn enough so that they know that what the program is doing, is what they want it to do. It's quite easy for a person to be confused; I've seen research papers published, in which the program was doing something different than the investigator thought it was doing, because he and the programmer had failed to communicate.

In the traditional closed shop computing center, we have what is called batch processing in which a number of jobs are executed in batches for machine efficiency. This denies the user the capability of knowing when his job is being run and of observing its execution, it also makes the time fairly long from when the job is submitted and is completed.

Newer machines are being developed with capability for many users to interact directly with the machine during execution of a job to share itself among several users. This is called time sharing. In such a system when a user gets to a point where he wants to stop a job and think, the machine won't be stopped, but go on and do something else. Such a system can serve a community of users, a fairly large number of users, relatively efficiently, but the important thing is that the people can be served efficiently. The result of this is going to be that there will be fewer small computers, and more large computers that are shared. People have preferred small computers, not because they were more easy to use, but because a human has been able to afford interaction with a small computer but not with a large computer.

At present we are in a transition, a really revolutionary transition, with computers at the present time. Most systems that are available commercially do not reflect the revolution; we are in the beginning of the revolution. We are making the transition from machines which are optimized for doing numerical computations to machines which are much better at doing the non-numeric part of our jobs, and which communicate much better with people.

In the future we are going to see a basic change in economics and a basic change in orientation. The cost of the machine is coming down dramatically. The cost per skilled man-hour is not going down at all. The cost of transmission of information is going down, but not narly so rapidly. This will cause a great change in the economic balance. Before many years have passed, the human cost will obviously become dominant. Maxfield said it is already sixty-forth, sixty per cent man costs, and forty per cent machine costs.

Another characteristic of the machines of the next generation is that they are going to be oriented toward information storage and retrieval, more than oriented toward computation.

I agree with Dick Maxfield that it is important, particularly with respect to the educational process, where human values are more important than machine values, that we retain control of what happens and the orientation of the processes with the educators, that we provide capability for local situations to be adapted to local needs. Now, there is going to be very high pressure because the cost of programming is high, and one can show from the national efficiency point of view that it is a good idea to have some federal agency of large computer manufacturer to do the programs for computer-aided instruction, that is, work out the curriculum, and have everybody ust it. I personally don't want to see that happen, but it is the cheapest thing to do. You're going to have to assess the human values involved, as contrasted to the absolute lowest cost way of doing these things, and I think it is up to you people, the educators, to understand this, and to become knowledgeable about what these things can do, and take a role in having them do the things that are useful. A computer is a powerful device. If I put a computer, or anyone else puts a computer into his organization, be it an industrial organization, a church, a school, whatever it is, and regardless of what he establishes as his initial goal, say he establishes as his goal as improving the efficience of reporting engineering progress in an engineering organization, or the reporting of student statistics in an educational situation, whatever it is, it will have much broader effect, because it will strengthen the area in which it is operating. It will shorten the communication time in the region of its application, so regardless of where you put it in, it will have an effect, it will have a broad effect. People in industry who have already applied these computers, have not always been happy with the results. One of the results is that middle management is cut out of the operation. The big boss gets the information digested immediately, which is acquired directly from the production line. No system is established by which middle management gets the information, or by which middle management gets less digested information. In these situations, we have deprived ourserves of the know-how of middle management. This has been a serious problem. We must, I think, in the educational system, keep this experience in mind, and because of the huge costs, share the development of procedures. Keep in mind that we must determine carefully what our goal is, try to assess what the effect will be on our primary human goals in education.

I would point out that you're going to be faced with the shared large computer and the individual small computer questions forever. At present, I believe, we are reaching the point in all cases which large computers are more satisfactory and usable for small jobs than before. Every school system has some large jobs. They don't have them every day. For example, the traditional data processing sort of things can be done by small computers very well. A job such as registration or class scheduling, is not a job which can be done by a small computer. I submit that in many cases we may be forced to take the large computer alternative because by only so doing can we pool our resources and be able to do large computing jobs. It is not really a question of preference, we must have large computers for some of the jobs. Can we also afford small computers or can these large computers also do the small computer job for us?

In the computer-aid instruction which has been done to date we can live with pretty small computing capability. I guess that in the future, we are going to have difficulty living with this small computing capability for our instruction. For example, a group in Massachusetts, using computers for the aid of teaching arithmetic, does not use the program textbook kind of approach. They give the computer to the student to experiment with, and he may try arithmetic experiments on the computer. He can explore arithmetic by means of an arithmetic machine. And whether that kind of a thing is a better educational tool than having a programmed teaching process is something we don't know yet. At the University of Utah we are about to begin an experiment on a larger scale in which we simulate engineering systems by computers and allow the student to experiment with these. We make the conjecture that this kind of a thing will be better for the superior students. This business of computer-aid instruction is distinctly a research area. Some of the possibilities require access to large computer capability. In my opinion, if one is doing experiments in computation for the aid of instruction, and one is keeping in mind economics, which one really has to do, one ought to weight most heavily the cost of communication and the cost of terminal equipment. The cost of processing is going to change dramatically relative to the cost of those things, and one should not be afraid of a system which involves complicated, logical processes in the computer if it doesn't complicate the terminal equipment.

My time is about up, and I would make one final comment. I am somewhat stimulated by Dick Maxfield's final comment. I believe in the use of the computer for preparing statistical reports for management, the school board, the school district, the principal, and the teacher at every level. What we are really looking for is changing patterns in student understanding and behavior. Any fair test of a man versus a machine as a pattern recognizor, will put the man way ahead.

Let's not let computer programmers deprive us of the valuable insights of experienced educators by depriving them of first hand access to the data and the students.

Thank you!